Climate feedbacks determine the sensitivity of the climate system to an external perturbation, affect the mean climate, and control the amplitude of natural variability. Thus validating and understanding feedbacks in climate models are of critical importance. Here we compare the feedbacks in CCM3—the atmospheric component of the NCAR CSM—with those from observations over the equatorial Pacific cold-tongue. The results show that the net atmospheric feedback in the model over this region is strongly positive (5.1 W m\(^{-2}\) K\(^{-1}\)) while in the real atmosphere it is strongly negative (-6.4 W m\(^{-2}\) K\(^{-1}\)). This discrepancy is largely due to errors in cloud feedbacks. Further noting a weaker surface heating over the cold-tongue in CCM3 than in observations, we suggest that the discrepancy in the atmospheric feedbacks may have contributed significantly to the cold biases in the equatorial Pacific in the NCAR CSM.

Results from Observations

Figure 1: Physical processes in the atmosphere. \(S_c\) is the clear sky solar radiation, \(G_1\) is the greenhouse effect of water vapor, \(C_1\) is the greenhouse effect of clouds, \(C_2\) is the short-wave cloud forcing, \(N_a\) is the net radiative flux at the top of the atmosphere, \(D_a\) is convergence of moist static energy in the atmosphere, and \(F_s\) is the net surface heat flux into the ocean.

Figure 2: The SST signal. Shown is the time series of SST anomaly over the Pacific cold-tongue (5°S-5°N, 160°E-290°E).

Figure 3: Response of the greenhouse effect of water vapor to the SST signal. Shown is the time series of \(G_a\) anomaly from ERBE over the Pacific cold-tongue.

Figure 4: Response of the long-wave and short-wave forcing of clouds to the SST signal. Shown are time series of \(C_1\) and \(C_2\) from ERBE over the Pacific cold-tongue.

Figure 5: Response of the net equatorial heat flux into the ocean to the SST signal. Shown is the time series of \(F_s\) over the Pacific cold-tongue. Data for \(F_s\) are the same as in Sun and Trenberth (1998).

Results from NCAR CCM3

Figure 7: Response of the long-wave and short-wave forcing of clouds to the SST signal. Shown are time series of \(C_1\) and \(C_2\) from CCM3 over the Pacific cold-tongue.

Figure 8: Response of the net equatorial heat flux into the ocean to the SST signal. Shown is the time series of \(F_s\) over the Pacific cold-tongue.

Figure 9: Response of the upper cloud cover to El-Nino warming in CCM3.

Figure 6: Response of the upper cloud cover to El-Nino warming in ISCCP data.

Table 1. Radiative and dynamic feedbacks from CCM3 and observations. The feedbacks are obtained through a linear regression.

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